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Upgraded DØ Calorimeter Electronics for Short Tevatron Bunch Space and the Effect of Pile-up on the W Mass Measurement

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UPGRADED DØ CALORIMETER ELECTRONICS FOR SHORT TEVATRON BUNCH SPACE AND THE EFFECT OF PILE-UP ON THE W MASS MEASUREMENT

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ABSTRACT

The high luminosity and short bunch spacing time of the upgraded Tevatron force the calorimeter to replace a significant part of the present electronics. The W mass measurement was used to study the pile-up effects.

1. Introduction

The present calorimeter electronics[1,2] was designed for 3.5μs Tevatron bunch spacing. The upgraded Tevatron will have a luminosity 5x10^{31}cm^{-2}sec^{-1} or higher and a bunch spacing time of 396ns or 132ns. These changes force the calorimeter to replace a significant part of the present electronics system near to the cryostat.

2. The Electronics Upgrade

The higher luminosity and the short bunch spacing result in higher electronics pile-up and very short time for trigger decision. The solutions are to decrease the shaping time and to add delay into the signal path for a trigger decision ($\sim$2μs). The shorter shaping brings up other problems: the electronics noise increases by a factor of two and the uranium noise decreases by one half; at higher frequencies the system might be more sensitive to coherent noise; all the mismatches and differences in cable lengths, impedances, module capacitances become significant[3,4].

The 100Ω twist-and-flat cable, causing an impedance mismatch between the feedthrough port and the preamplifier, will be replaced by 30Ω coaxial cable and the total length of the inner and outer cables will be equalized for all channels. The two FETs at the preamplifier input lower the input impedance and match it to the coax cable. The effect of the module capacitance is eliminated by pole zero compensation in the preamplifier[5]. A driver stage is added to the preamplifier to drive the terminated 100Ω cable between the preamplifier and BLS.(Fig.1.)

At present two possible solutions are being considered for delaying the analog signal during the trigger decision: Analog Delay Line (ADL) and Switched Capacitor Array (SCA).

In Fig.2. the ADL version is shown. The ADL is simple but sensitive to magnetic field[6]. After the delay line there is a differentiation and a unipolar Sallen-Key filter[7]. The subtractor after the filter produces the difference of the base line between superbunches and the signal at a given crossing. Only one sample is taken within a superbunch. The further elements in the BLS remain unchanged.

In Fig.3. the SCA version of BLS is shown. The SCA[8] is an analog storage device using addressable floating capacitors for charge/voltage storage. The SCA, typically 16 channels x 32 capacitor cells, stores signals from multiple crossings around the trigger.

A trigger signal with proper width can be generated at 396ns bunch spacing. A study was made to shorten the trigger pick-off [5] to accommodate to the 132ns bunch spacing.

The upgrade timing requires an accumulated ±10ns long term stability.

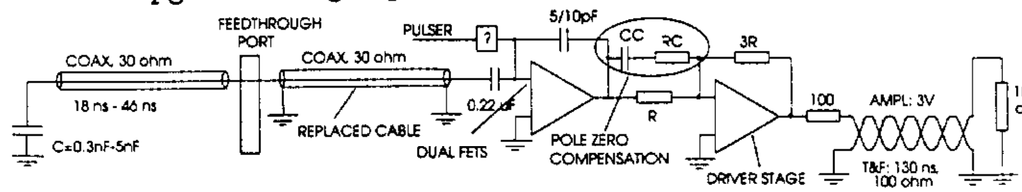

Figure 1: Upgraded preamplifier and cabling

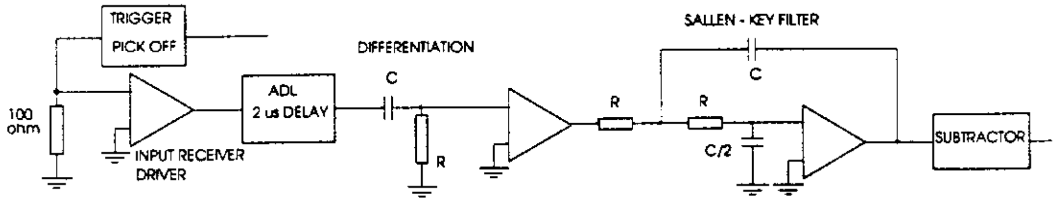

Figure 2: The delay line (ADL) version of the upgraded BLS

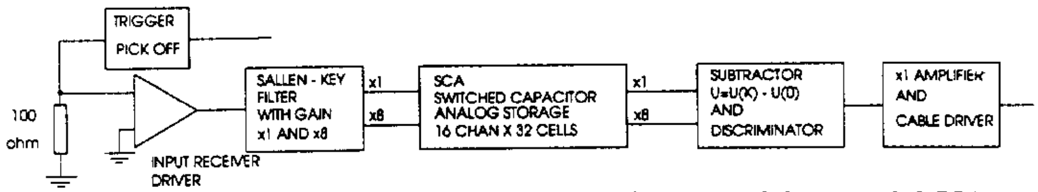

Figure 3: The switched capacitor (SCA) version of the upgraded BLS

3. Pile-up effect on the W Mass Measurement

In the calorimeter system the pile-up, which means the overlap of additional background events on the signal events, originates from two different sources. At high luminosity more than one collision can happen at one crossing (physics pile-up) and additionally the readout electronics may contain signals originating from the previous and subsequent crossings (electronics pile-up). A study was made to analyze the pile-up effect on W mass measurement[9,10].

The W transverse mass (using $W \rightarrow e\nu$ decay) can be deduced from the invariant mass equation: $Mt_W^2 = 2\, Pt_e\, Pt_\nu\, (1 - cos\phi)$. Using the independently measured variables at the calorimeter we can rewrite the mass equation as

$$Mt_W^2 = \left[Pt_e + \sqrt{Pt_e^2 + Pt_W^2 - 2Pt_e Pt_W cos\psi} \right]^2 - [Pt_W]^2. \tag{1}$$

The method calculates the pile-up effects by comparing for each event its characteristic with and without pileup. The result is a W transverse mass difference for every event. The average and the resolution of this difference distribution are the shift and the resolution change of the W transverse mass owing to pile-up. *The shift and the resolution change are the basic quantities used in the study.* A W event group without pile-up and a background event group were generated by ISAJET+GEANT. A program combined the two groups into a W event group with pile-up by adding physics and electronics pile-up to each signal event. The physics pile-up is the addition of background events into the present and the neighboring crossings randomly according to a poisson distribution resulting from the average occupancy rate. The electronics pile-up is realized by adding the background events with proportional amplitude.

For studying the effect of the pile-up (or any noise) on the Pt_W or Pt_ν an analytic calculation was also developed[10]. If the signal distribution average is far from zero (the method uses the signal reciprocal average), the analytical and simulation results agree quite well. The advantage of this method is the separation of the pile-up (noise) distribution from signal event distribution.

The pile-up study with W events covers the following important cases:
OR: Present, 3.5μs crossings, 10^{31} luminosity, 2.2μs sampling electronics.
UP-3: 396ns crossings, 5x10^{31} luminosity, 400ns shaping time.
UP-1: 132ns crossings, 5x10^{31} luminosity, 400ns shaping time.

To set the scale for the resolution degradation from pile-up, the study calculated the "intrinsic" resolution without any pileup: $(\delta Mt_W)_i = (Mt_{W,np})_i - (Mt_{W,ISA})_i$. The result is $\sigma(\delta_I Mt_W)_i = 5.17 \pm .07 GeV$. The following table shows the most important results:

1.Table RESOLUTION AND MEAN CHANGE OF Mt_W FROM PILE-UP

CASES	$\sigma(\delta Mt_W)$ Eq. (2) GeV	$\sigma(Mt_W)$ TOTAL GeV	δMt_W SUM MeV	Pt_e TERM MeV	Pt_W TERM MeV
OR	3.11 ±.04	5.87 ±.08	100 ±24	199 ±18	-99 ±13
UP - 3	2.95 ±.04	5.88 ±.08	149 ±22	232 ±17	-83 ±14
UP - 1	2.84 ±.05	5.75 ±.08	142 ±21	223 ±13	-84 ±14

where $\sigma(\delta Mt_W)$ is the pile-up contribution to the W transverse mass resolution, $\sigma(Mt_W)$ is the total W transverse mass resolution and δMt_W is the shift in the W transverse mass. We can see that the resolution degradation is not serious but the shift (bias) in the W mass is noteworthy: the electron term is around +200MeV and the underlying events term is around -100MeV. We do not see significant differences among the three cases. ORI-3.5 and UP-3 have similar occupancy rate (1.94 and 1.82 respectively) and the signal shapes for both match to one crossing. UP-1 has 0.31 occupancy rate, but the signal, being the same as the one for UP-3, covers 3 crossings so the end result becomes the same.

4. References

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